INTERSPEECH 2023
20-24 August 2023, Dublin, Ireland

Durational and non-durational correlates of lexical and derived geminates in Arabic

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Abstract

This paper reports on the phonetic and phonological patterns of gemination in Tripolitanian Libyan Arabic (TLA). While previous studies on Arabic gemination have either focused on lexical geminates or reported results on data that contains both lexical and derived geminates, without investigating its effect on the phonetic output, the present study investigates the effect of the phonological status of a geminate on the phonetic realization. Several measurements were obtained including target segments duration, RMS amplitude and F1, F2 and F3 for the target consonants. Preliminary results suggest that the acoustic distinction between singleton and geminate consonants in TLA is dependent mainly on durational correlates. There was no evidence of differences in RMS amplitude between singleton and geminate consonants of any type. F1, F2 and F3 frequencies are found to show similar patterns for singleton and geminate types for all sounds, suggesting no gestural effects of gemination in TLA.

Index Terms: Arabic, lexical and derived geminates, acoustic correlations, duration, RMS amplitude, Formant frequencies.

1. Introduction

Durational and non-durational variations in geminate consonants have been investigated for many languages (e.g. [1, 2] for Italy; [3] for Cypriot Greek; [4] for Berber). The durational correlates of geminates have formed the main focus in investigating the singleton-geminate contrast traditionally and, generally, studies in various languages have shown that duration is the most robust correlate of gemination (see e.g. [1] and [3], among others). Arabic geminates also reported to be significantly longer than their singleton counterparts (see e.g. [5, 6]).

Some studies have suggested that other non-durational correlates of geminates exist and argued that these characteristics contribute to the perceptual effect of gemination. These include, for example, a higher root mean square (RMS) amplitude for geminate stop release [4], a palatalized configuration for geminate sonorants [7] and geminate laterals [1], more lenited stops in singleton contexts [4], and differences in the quality of the sonorant geminates as opposed to their singleton counterparts, while geminates appear to affect the duration and quality of preceding segments as well [8]. The argument is that some of these cues are suggestive of a tense/lax distinction between singleton and geminate consonants alongside durational contrasts (see e.g. [9] and [4]). Although these non-durational cues are found to be salient for some languages, the results are not consistent across languages. For instance, [10] report evidence from several types of measurements that non-durational cues to gemination do not exist in Cypriot Greek.

In TLA, Geminate and singleton consonants are contrastive. All consonants in LA can be geminated. Vowel length is also phonemic, and both short and long vowels can occur before geminate consonants. In addition to lexical contrastive geminate consonants ('True geminates'), TLA has two types of post-lexical phonologically derived geminates: concatenated geminates and assimilated geminates. Concatenated geminates can be formed as a combination of two identical consonants at the juncture of a word or a morpheme ('fake geminates'). Assimilated geminates are the result of total assimilation in consonant clusters ('assimilatory geminates') (see Table 1 for examples). Previous studies on Arabic have either focused on lexical contrastive geminates or reported results on data that consists of more than one geminate type without investigating the effect of its phonological status on the phonetic output. It will be useful to investigate whether this difference triggers any acoustic consequences. In addition, it is worth pointing out that the non-durational cues to gemination have not been previously examined for the three geminate types even in the languages where these correlates are found to be salient, as mentioned above.

While consonant gemination in TLA is very frequent and plays an important role in the grammar of the language, very little is known about the phonetic realisation of gemination in this dialect. This study contributes to the literature on gemination and the literature on Arabic language by providing a detailed examination of both the durational and non-durational acoustic correlates of the singleton-geminate contrast and the three geminate types using approximant sounds in TLA. While most of the phonetic studies on Arabic gemination have focused on the durational cues of the singleton-geminate contrast, this study looks at a variety of non-durational correlates as well as durational ones. In this study, the three intervocalic geminate types (true, fake and assimilatory) will be investigated acoustically in order to get a picture of what phonetic consequence the phonological status of a geminate might have.

2. Method

2.1. Speakers

Four native speakers (3 males, 1 female) of TLA, a dialect of Arabic spoken in the North-West region of Libya (a country in the Maghreb region of North Africa) known as Tripolitania (Trablus) province, were recruited. They ranged in age, at the time of recording, from 30 to 38 years, and had no obvious speech or hearing defects.

10.21437/Interspeech.2023-2187

2.2. Stimuli and data recording

A list of 30 real minimal or near-minimal utterances divided into eight sets was compiled. Each two sets contain one of the approximant sounds /r, l, m, n/ both as singletons and three geminate types in word-medial/utterance-medial intervocalic position preceded by short and long vowels, with the exception of the alveolar nasal /n/, which have only two geminate types due to the lack of the assimilatory geminate. The spelling and diacritics of the words followed the TLA regional pronunciation. Table 1 shows an example of one of the sets compiled for the alveolar rhotic /r/. Each one of the speakers was asked to read a list composed of 108 utterances (30 randomized utterances x 3 repetitions + 6 filler words x 3 repetitions). Each target utterance was produced in the carrier sentence [gæ:l aħmid _____ tæ:ni] "Ahmed said _____ again".

Table 1: *An example of one of the sets compiled for the alveolar rhotic /r/.*

/r/			
	/ˈma**r**a:mi/	'goalkeepers'	Singleton
	/ˈba**r:**a:ni/	'stranger'	True geminate
/sir#ra:m/→	[ˈsi**r:**a:mi]	'The secret of Rami'	Fake geminate
/min#ra:mi/ →	[ˈmi**r:**a:mi]	'who is Rami?'	Assimilatory geminate [n→r]

2.3. Data analysis and measurements

A total corpus of 360 utterances (30 utterances x 3 repetitions x 4 speakers) were extracted from the list each into a separate wavfile for auditory and acoustic analysis. Durational measurements (in millisecond) of the singleton consonants, the different geminate types and the preceding vowels were made using PRAAT [11].

The data were labelled semi-automatically using Praat annotation text grids relying on both the spectrogram and the corresponding waveform. The durational measurements were obtained using a script and checked by hand. Additional measurements were obtained automatically using specifically designed scripts. The acoustic measurements conducted in this study include the following:

- The duration of the singletons and (the three types of) geminates.
- RMS amplitude differences between the singleton-geminate contrast and between the three geminate types.
- F1, F2, and F3 of the singletons and (the three types of) geminates.

An oral constriction criterion [12] is used to segment all the target speech sounds. In this method, the onset and release of oral consonantal constriction is used to identify the sound boundaries. RMS amplitude was measured over the duration of the target segments in decibel (dB). The RMS values were normalized by dividing its value by that of the preceding vowel. F1, F2, and F3 were measured at the midpoint of the target consonants. The results are based on a series of independent analysis of variance (ANOVAs).

3. Results

3.1. Durational correlates

An ANOVA testing the durational differences between singletons and each geminate type show that the phonological status is significant ($F(3,11)=62.496$, $p<0.001$), the sound category is significant ($F(3,12)=6.887$, $p<0.05$), and the speaker is not significant ($F(3,13)=0.668$, $p=0.586$). The three-way interaction of phonological status x sound x speaker is not significant ($F(24,30)=1.350$, $p=0.130$). This result shows that the durational differences between singleton consonants and each geminate type separately also achieves significance with no effect of speaker reflecting consistency in the durational contrast between singletons and each geminate type for all speakers.

Table 2: *Mean duration (in ms), standard deviation and the number of tokens for singleton consonants and the three geminate types and the ratio of C to CC.*

	Phonological Status			
	Singleton	True geminate	Fake geminate	Assimilatory geminate
Mean	**50.4**	**118.6**	**126.7**	**121.7**
SD	21.4	28	18.7	27.9
Total N	96	96	96	72
C to CC		**1: 2.35**	**1: 2.51**	**1: 2.41**

The results in Table 2 show that Fake geminates are about 2.5 times as long as their singleton counterparts whereas True geminates and Assimilatory geminates are about 2.3 and 2.4 times as long as their singleton counterparts respectively.

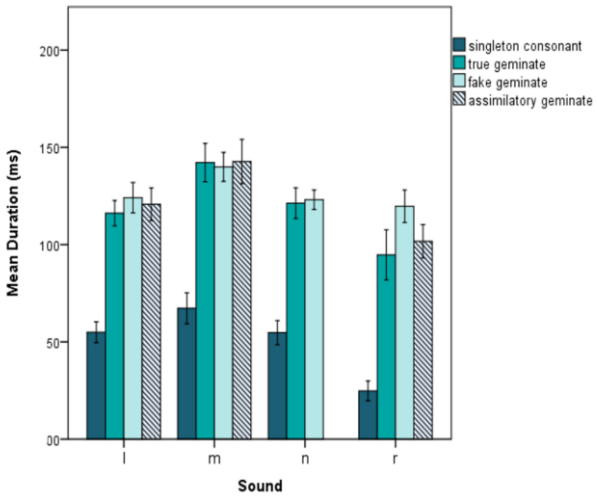

Figure 1: *Mean duration (in ms) and standard deviation of each of the consonant categories in singletons and the three geminate types.*

Figure 1 shows durational results for each of the four sounds in the singleton and three geminate types contexts. It is clear from Figure 1 that there is a consistency in the durational behaviour of these sounds in the context of C and CC regardless

of geminate type. In both C and CC contexts the shortest consonants are rhotics (except for Fake geminates /r/ which show similar duration to the alveolar nasal and alveolar lateral) followed by both the alveolar nasal and the alveolar lateral (which show similar durational patterns), with the bilabial nasal being the longest. Figure 1 shows that all geminate types for each sound are significantly longer than their singleton counterparts.

ANOVA shows no significant durational differences between the three geminate types ($F(2,4)=1.294$, $p=0.353$), the sound category is significant ($F(3,10)=5.352$, $p=<0.05$), and the speaker is not significant ($F(3,8)=1.884$, $p=0.203$). The interaction between the geminate type and sound category is not significant ($F(5,15)=2.700$, $p=0.062$). The interaction between the geminate type and speaker is not significant ($F(6,15)=1.272$, $p=0.327$), which suggests that the speakers' durational patterns of the three geminate types are similar. The three-way interaction of geminate type x sound x speaker is also not significant ($F(15,22)=1.397$, $p=0.150$). Post-hoc tests reveal that the durational difference between True geminates and Fake geminates approaches significance ($p=0.051$). The difference between True and Assimilatory geminates is not significant ($p=0.754$). The difference between Fake and Assimilatory geminates is not significant as well ($p=0.393$).

3.2. Non-durational correlates

ANOVA shows that the RMS amplitude differences between the singleton and each geminate type did not achieve significance ($F(3,9)=0.344$, $p=0.790$). The sound category is not significant ($F(2,6)=1.300$, $p=0.340$) and the speaker effect is not significant ($F(3,4)=5.045$, $p=0.062$). The interactions between the phonological status and sound category ($F(6,18)=0.359$, $p=0.895$) and phonological status and speaker ($F(9,18)=0.731$, $p=0.676$) are also not significant. This reflects a consistency in the RMS values for the sounds across speakers. Post hoc LSD tests failed to show any significant difference between the levels of the factors tested here. Figure 2 shows the RMS results for the singleton and the three geminate types.

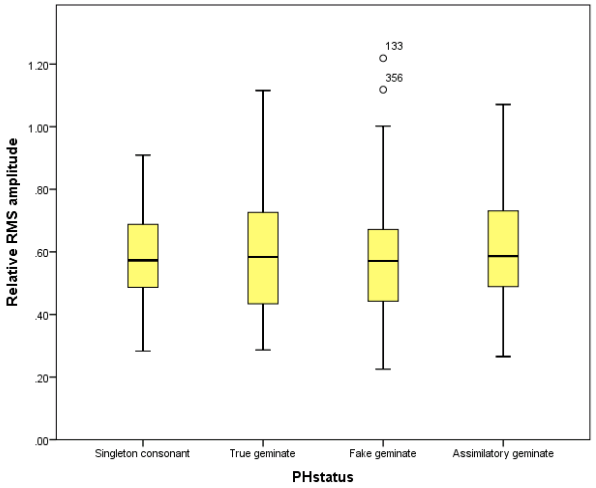

Figure 2: *Relative RMS amplitude values for singleton and the three geminate types.*

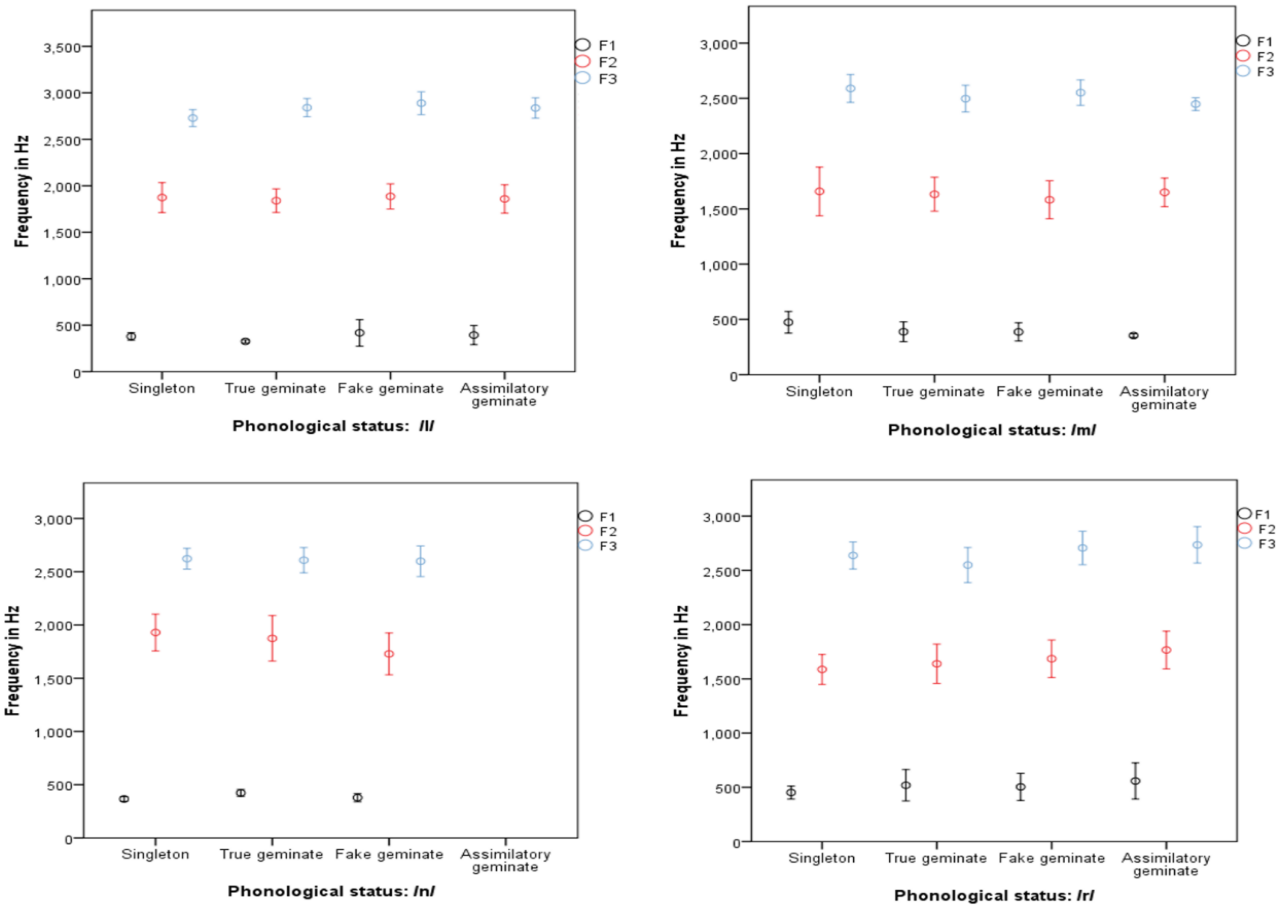

Figure 3: *Mean frequency (in Hz) of F1, F2 and F3 in /l/, /m/, /n/ and /r/ as singletons, true, fake and assimilatory geminates.*

The RMS amplitude differences between the three geminate types did not achieve significance either ($F(2,6)=0.412$, $p=0.680$). The sound category is not significant ($F(2,6)=0.803$, $p=0.491$) and the speaker effect is not significant ($F(3,5)=4.750$, $p=0.059$). The interactions between the phonological status and sound category ($F(4,12)=0.452$, $p=0.769$) and phonological status and speaker ($F(6,12)=30.967$, $p=0.486$) are also not significant. The interaction between the three factors (geminate type x sound x speaker) is also not significant ($F(12,17)=1.496$, $p=0.129$). This reflects a consistency in the RMS values for the three sounds across speakers and across geminate types. Post hoc comparisons also fail to show significant differences in RMS amplitude between the three geminate types.

The extracted F1, F2, and F3 values were analysed in factorial ANOVAs each separately to test the singleton-geminate contrast and the three geminate types. As can be seen from Figure 3, even though the formant frequencies can be different for the different sounds, the general tendency indicates that a geminate consonant (and type) has no effect on the formant structure of the target segments in TLA. As Figure 3 shows, F1 does not contribute to the singleton-geminate contrast. The phonological status of the geminate shows no effects on F1 across the four sounds either. ANOVA shows that the phonological status is not significant ($F(3,5)=0.038$, $p=0.989$), the sound category is not significant ($F(3,10)=2.268$, $p=0.141$), and the speaker is not significant ($F(3,7)=0.209$, $p=0.887$). The interactions between the phonological status and sound category ($F(8,24)=1.799$, $p=0.127$) and phonological status and speaker ($F(9,24)=0.817$, $p=0.563$) are also not significant. Post hoc LSD test also fails to show any significant differences between the levels of these factors. No significant differences could be found for F2 between the levels of the phonological status for all the sound types. ANOVA shows that the phonological status is not significant ($F(3,2)=0.798$, $p=0.584$), the sound category is not significant ($F(3,8)=1.077$, $p=0.408$), and the speaker is not significant ($F(3,8)=2.630$, $p=0.116$). The interactions between the phonological status and sound category ($F(8,24)=0.847$, $p=0.572$) and phonological status and speaker ($F(9,24)=0.882$, $p=0.555$) are also not significant. Post hoc LSD test also failed to show any significant differences between any of the levels tested. The phonological status of the consonant has no effect on F3 for all the sound types. This is confirmed by statistical testing. ANOVA shows that the phonological status is not significant ($F(3,1.7)=1.099$, $p=0.522$), the sound category is significant ($F(3,8)=5.389$, $p=0.022$), and the speaker is significant ($F(3,5)=14.075$, $p=0.006$). The interactions between the phonological status and sound ($F(8,24)=1.313$, $p=0.284$) and phonological status and speaker ($F(9,24)=0.384$, $p=0.913$) are not significant, however. This significant effect of the sound category is resulting from F3 frequencies for the alveolar lateral /l/ that are considerably higher (around 2700 Hz for the singletons and 3000Hz for the three geminate types) than F3 for the other sound types. A deeper look at the data revealed that the significant effect of the speaker factor is resulting from the higher F3 frequencies of the female speaker compared to that of the male speakers. F3 is higher for the female speaker for all singletons and geminates (of all types) (around 2900-3000 Hz) across all sound types compared to male speakers (around 2500-2600 Hz), which is expected as an effect of gender on Formant frequencies. However, this gender effect is not present in the analysis of F1 and F2. Post hoc LSD tests failed to show any significant differences between any of the levels tested, which confirms that the significant sound and speaker effects found here do not result from differences between the singleton and geminate consonants or the three geminate types. That is, gemination has no effect on F3 regardless of sound type and speaker.

4. Discussion and Conclusion

The aim of this study was to investigate whether the phonological status of singleton and (the three types of) geminate consonants condition their intrinsic acoustic properties. It has presented evidence from several types of measurements on the acoustics of gemination in TLA. The results emphasize the significant role of duration as consistent and robust cue to gemination for all types of sounds involved. The duration of geminates in this study is generally comparable to what has been found for Jordanian Arabic [6], and Lebanese Arabic [13, 5], with the duration of a geminate consonant being around twice as long as its singleton counterpart. The three geminate types are found to have similar durational patterns across sound types. That is, lexical and derived geminates have similar durational patterns.

In addition to the duration of the target segments themselves, other types of evidence relating to the acoustic characteristics of geminates have been investigated here. I was prompted to undertake this investigation because of the findings, reported for some languages, that gemination may indeed involve several acoustic parameters in addition to duration ([8], [14], [9]). However, neither of these proposals has been supported by the data from this study. There were no differences in RMS amplitude between singletons and geminate consonants of any type. RMS differences between the three geminate types were not significant either. The higher amplitude of geminates reported in the literature could be considered as a concomitant correlate of manner of articulation and not to phonological length of these long segments since the analysis was dependent on results from data using geminate stops (see [14] and [15]). Formant frequencies of the target consonants were used in this study to evaluate potential qualitative differences linked with the singleton-geminate contrast and the three geminate types. The formant analysis was used by some researchers to test for the presence of gestural differences between geminates and non-geminates (see [1] [8]). However, this proposal has not been supported by the data from the current study. No evidence could be found for the effect of the phonological status on the first three formants. The result of the current study provide evidence that the structure of F1, F2 and F3 is consistent across the singletons and the three geminate types regardless of sound type, which shows that gemination has no effect on the formant structure of approximant sounds in TLA suggesting stability in the articulatory gesture. A possible interpretation for this result is that the presence of differences in F1, F2 and F3 between singleton and geminate consonants and the three geminate types is language specific.

To sum up, the results from the phonetic cues investigated here suggest that the acoustic distinction between singleton and geminate consonants in TLA is dependent mainly on durational correlates and that non-durational acoustic cues do not contribute to this distinction. However, duration does not serve to distinction between lexical and derived geminates (of any type). Non-durational acoustic cues do not distinguish between the three geminate types as well. It is fair to say, however, that the results are based only on approximant sounds and further research involving other segment types will be necessary.

5. References

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